

Improvement of vertical profiles of raindrop size distribution from micro rain radar using 2D video disdrometer measurements



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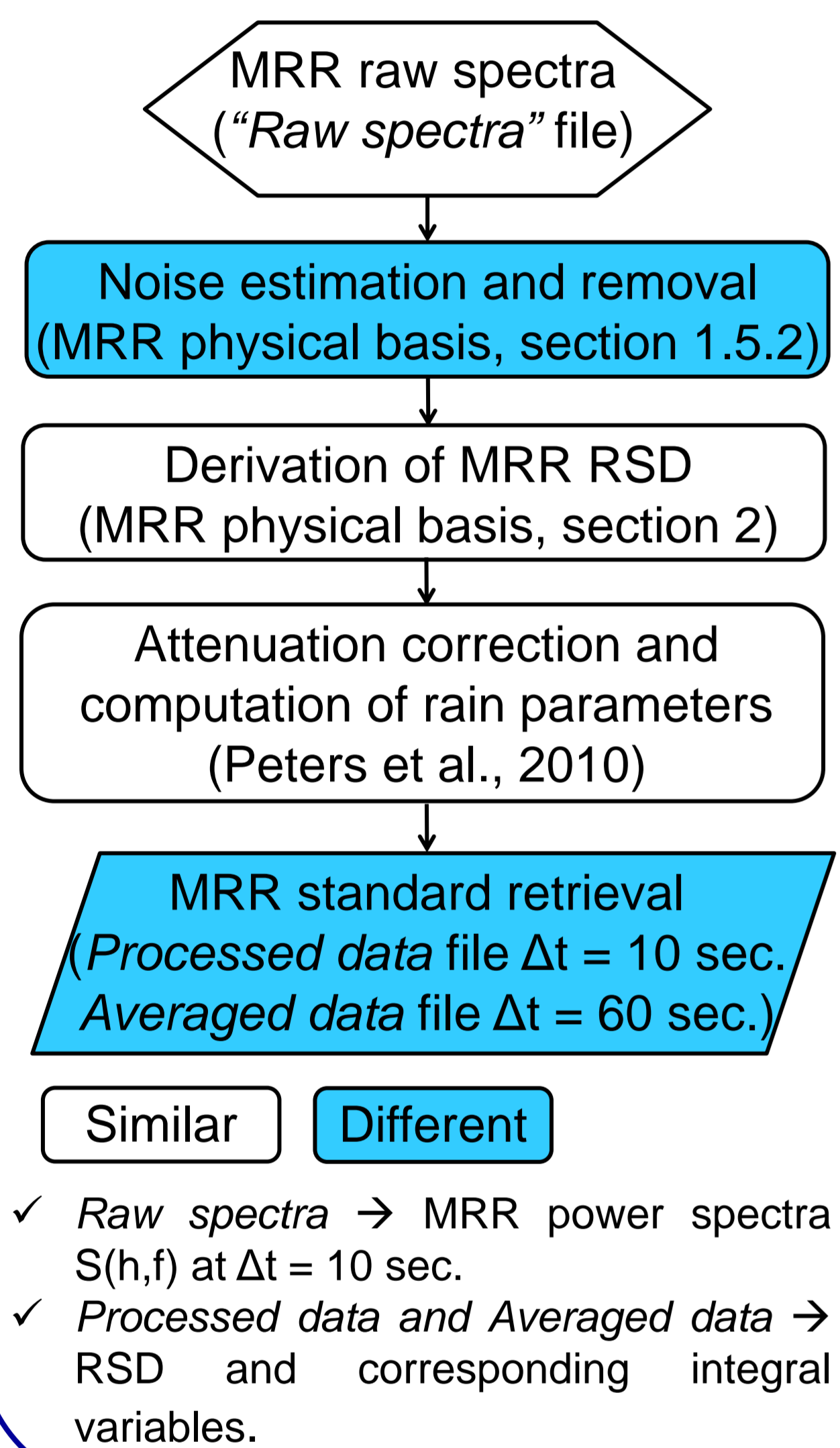
Rationale

- A number of RSD datasets collected with disdrometers (such as 2D video disdrometer, **2DVD**) and profilers (such as K-band vertically pointing micro rain radar, **MRR**) are available in **several climate regions** from GPM GV campaigns, but **few related studies have utilized the MRR**. This is mainly due to the **questionable validity of standard MRR products in heavy precipitation or convection**. Vertical winds, attenuation correction, Doppler spectra aliasing, and range-Doppler ambiguity can limit the performance of MRR in these conditions.
- A precarious assumption used in the MRR standard processing to retrieve the RSD is that the vertical wind is negligible. This assumption is not very appropriate during convection, where the presence of up/down draft can shift the measured velocity spectrum leading to an inaccurate retrieval of the RSD and thus bias integral parameters..

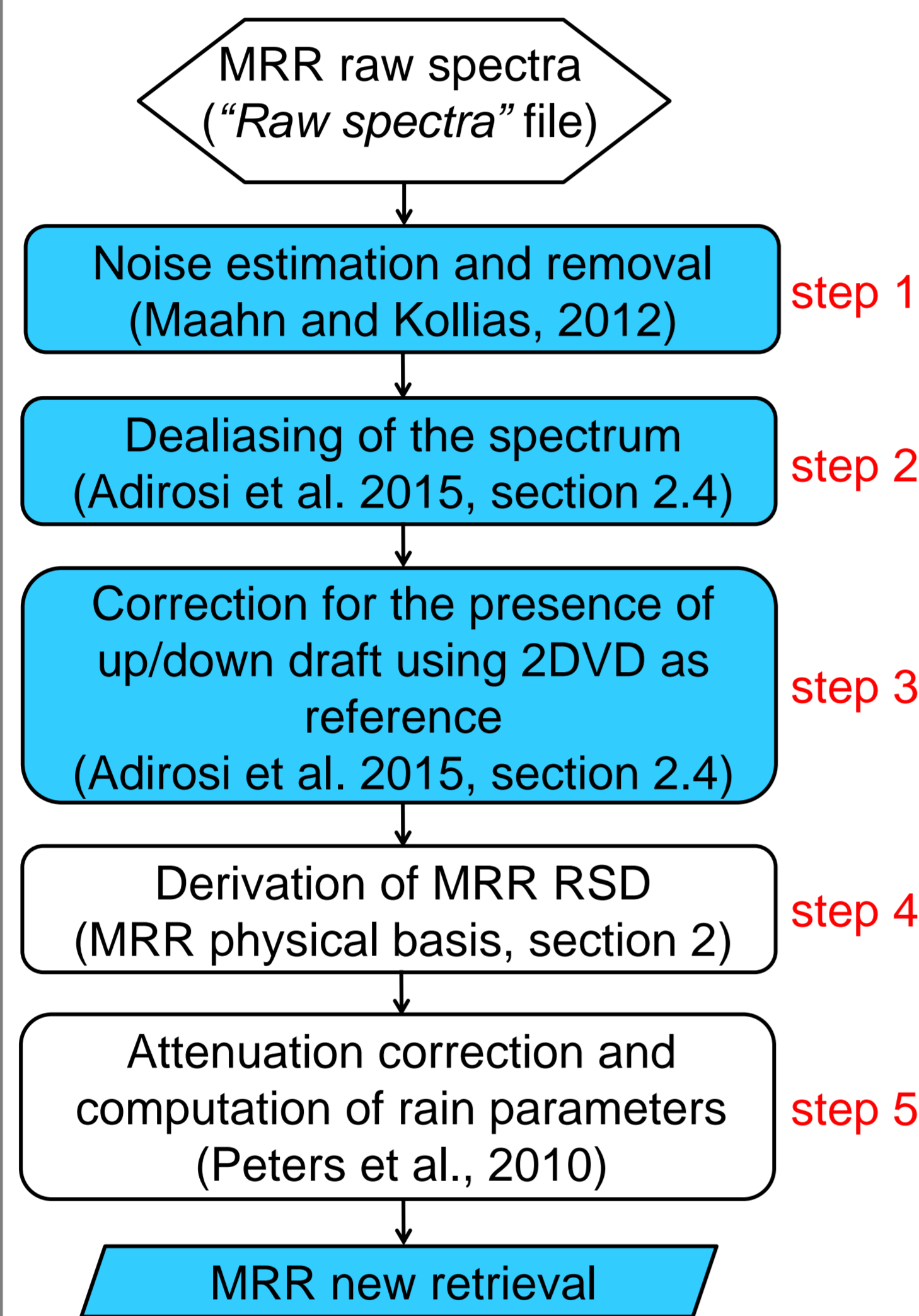
Objectives

- Datasets of MRR spectra can be properly reprocessed exploiting the synergy with coincident 2DVD measurements to reduce uncertainty of MRR profiles estimates and to increase the reliability of MRR data.
- In particular, **MRR Doppler spectra are reprocessed**, exploiting the **2DVD measurements** at ground to estimate the **effects of vertical winds** at 105 m (the most reliable MRR lower height), to provide a better estimation of vertical profiles of RSD.
- MRR and 2DVD installed close each other at a site in the historic center of Rome (Italy) during the Special Observation Period 1 of the HyMeX (Hydrological Cycle in the Mediterranean Experiment) project, (5 September - 6 November 2012) are used to evaluate the proposed method.

MRR standard processing



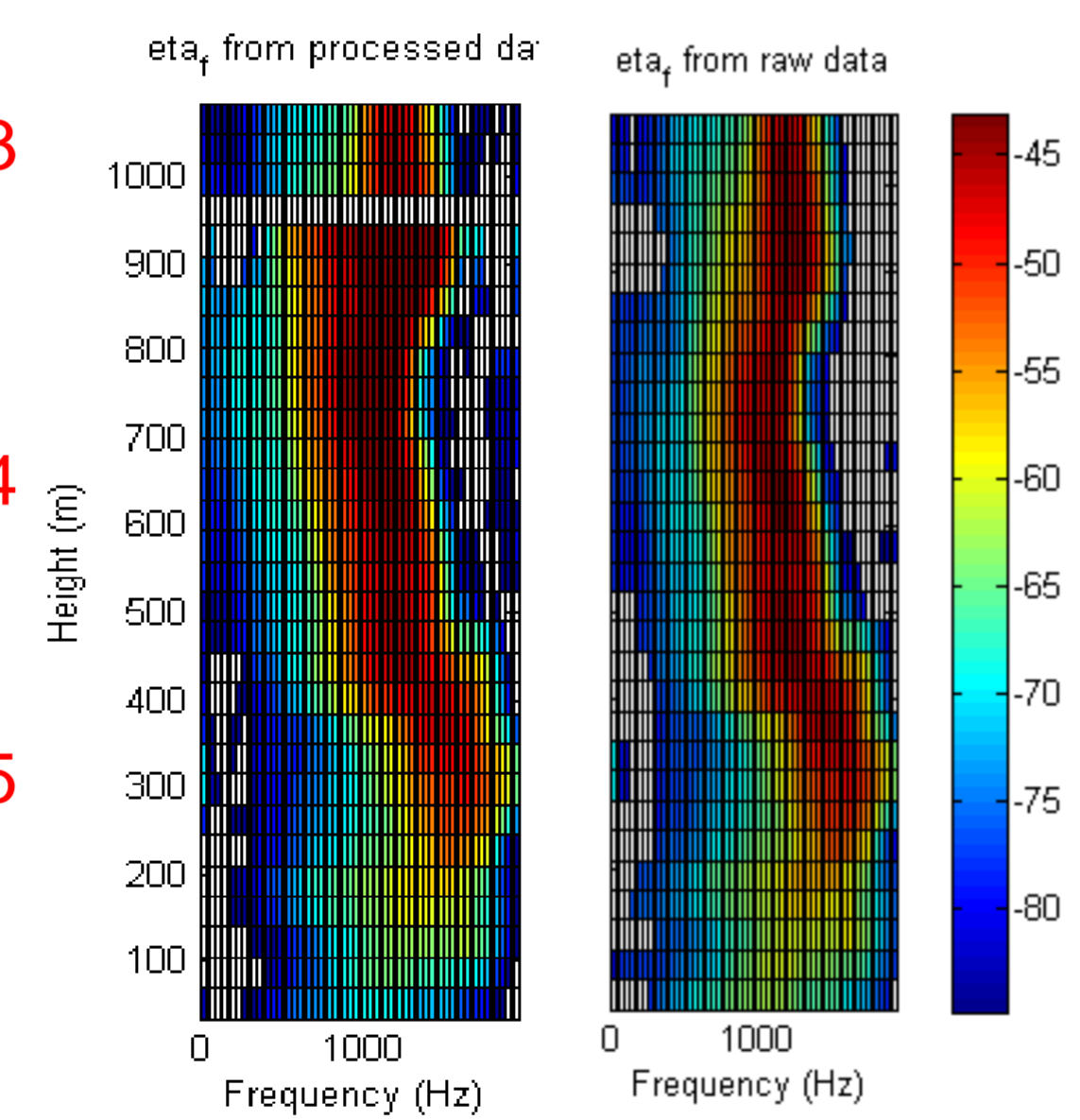
MRR new processing



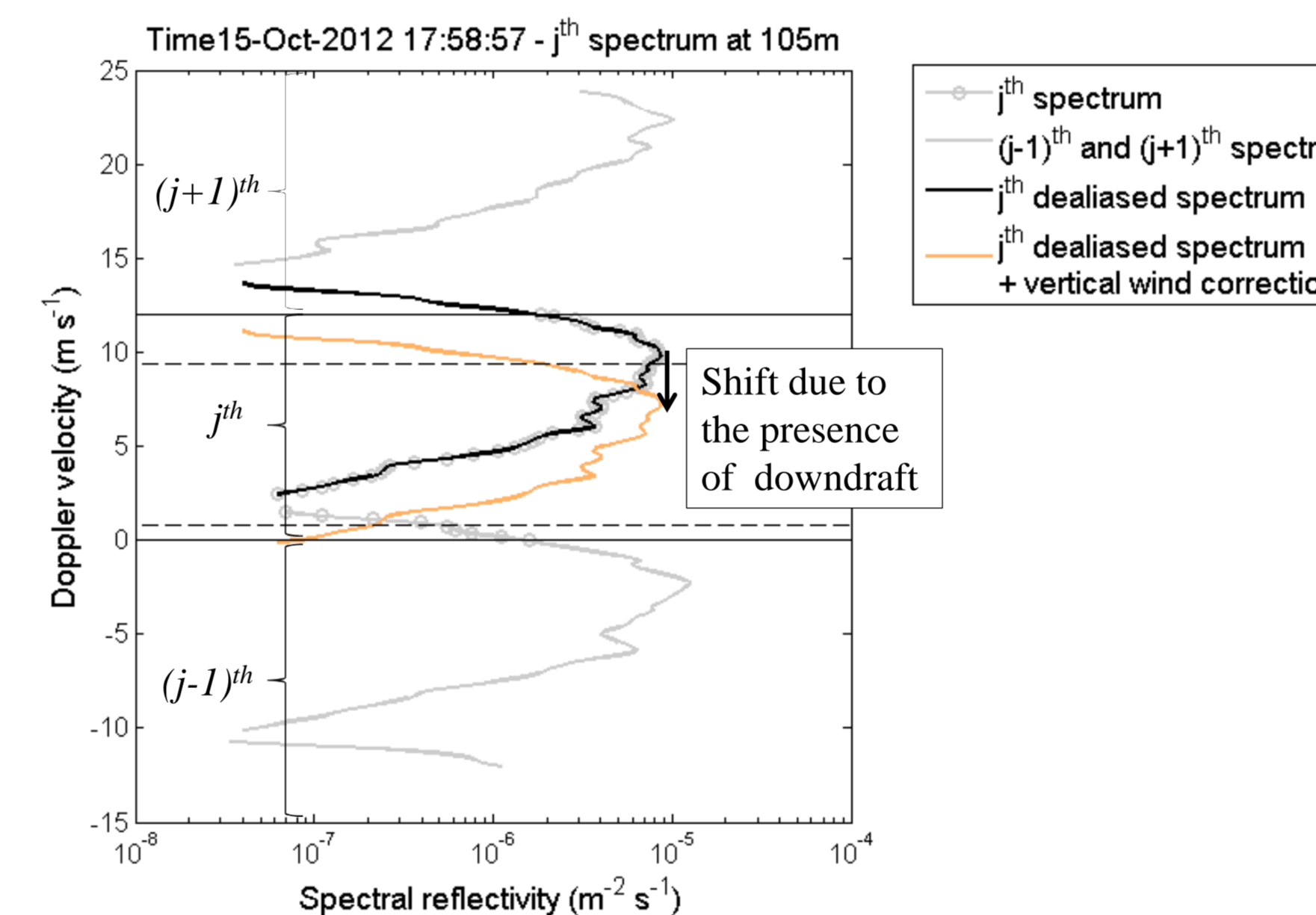
MRR Processing

Step 1: noise removal

Example of reflectivity spectra from standard *Processed data file* (15 October 2012 at 18:01:27 UTC) (left) and those obtained applying the noise removal procedure by Maahn and Kollias (2012) to raw spectra (right).



To unfold the spectrum of the j -th range gate we consider the two adjacent spectra. Starting from the peak of the j -th spectrum the lower (or upper) limit of the j -th spectrum is the first bin between the peak of the j -th spectrum and the peak of the $(j-1)$ -th (or $(j+1)$ -th) spectrum with a value of spectral reflectivity lower than the noise level, or, if it does not exist, with the bin corresponding to the minimum values of the spectral reflectivity.



Step 2: dealiasing

The characteristic fall velocity of 2DVD $v_{c,2DVD}(D) = \frac{\int_{D_{min}}^{D_{max}} v_t(D) N(D) \sigma_b(D) dD}{\int_{D_{min}}^{D_{max}} N(D) \sigma_b(D) dD}$ is matched to the one obtained from the MRR spectra at 105 m

$$v_{c,MRR} = \frac{\int \eta_v(v) v dv}{\int \eta_v(v) dv}$$

$N(D)$ = 2DVD measured RSD, $v_t(D)$ = terminal fall velocity, $\sigma_b(D)$ = backscattering cross section area computed at 24.243 GHz, and $\eta_v(v)$ = dealiased Doppler spectrum of MRR.

The velocity difference at 105 m has been used to correct all the range gates.

Assumptions:

- the vertical change in RSD within the lowest 100 m is negligible
- the vertical motions are near zero at the height of the 2DVD measurements (at ground)
- the up/down draft does not vary significantly within the lowest 1 km AGL (e.g. Giangrande et al. 2013).

Step 3: correction for up/down draft

At all the different elevations, the RSDs have been estimated normalizing the spectral reflectivity density with respect to drop diameter

$$\eta_D(i, j) = \eta_v(i, j) 6.18 \exp(-0.6 D) \delta(h) \text{ by } \sigma_b(D)$$

$$N(D, i) = (\eta(D, i)) / (\sigma(D))$$

Step 4: RSD retrieval

The technique for attenuation correction by Peters et al. (2010) was applied to processed raw spectra. Spectra with path integrated attenuation greater than 10 dB, were discarded.

Step 5: attenuation correction

Validation of MRR new processing

- AVE@105 → Reflectivity or RSD from MRR standard processing in the *Average data* file at 105 m
- NEW@105 → Reflectivity or RSD from the MRR new processing at 105 m

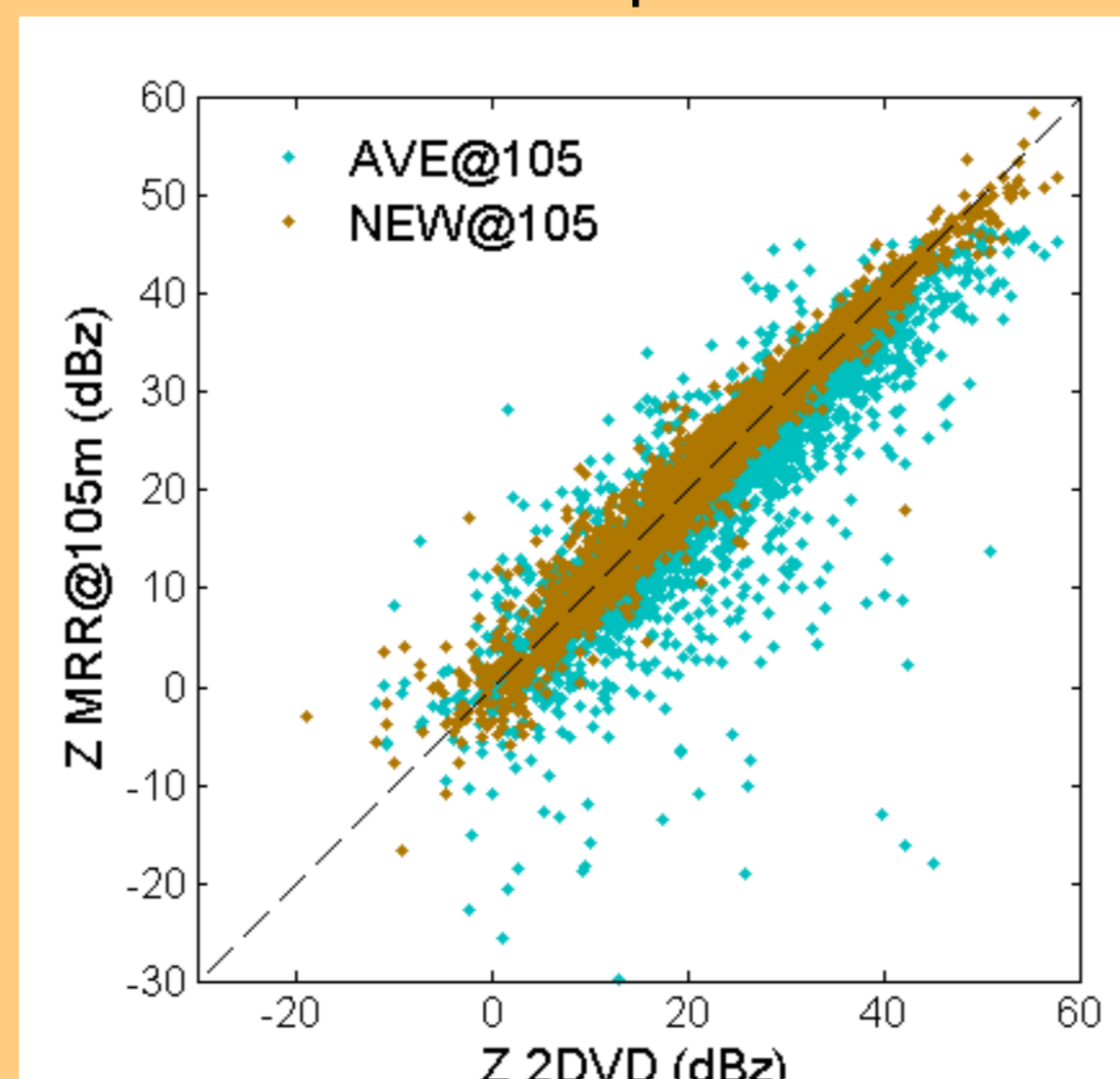
Reflectivity comparison

day	C/S classification		Z_{2DVD} vs $Z_{AVE@105m}$			Z_{2DVD} vs $Z_{NEW@105m}$		
	% convective minutes	% stratiform minutes	NSE	NB [dB]	cc	NSE	NB [dB]	cc
0913	9	89	2.35	-0.57(-3.70)	0.867	0.72	-0.05(-0.21)	0.977
0914	0	98	1.05	-0.39(-2.12)	0.901	0.60	0.17(0.70)	0.958
0930	6	90	3.95	-0.57(-3.67)	0.630	1.19	-0.06(-0.26)	0.974
1012	22	74	3.53	-0.73(-5.68)	0.643	2.52	-0.32(-1.71)	0.845
1015	13	86	2.71	-0.78(-6.59)	0.829	2.13	-0.17(-0.81)	0.810
1026	3	93	1.70	-0.50(-3.06)	0.422	0.57	-0.04(-0.16)	0.946
1031	2	96	4.00	-0.47(-2.78)	0.475	4.56	0.23(0.90)	0.656
1111	7	92	2.59	-0.49(-2.98)	0.633	0.81	0.04(0.17)	0.965

- Normalised standard error: $NSE = \frac{\sqrt{(x-y)^2}}{\bar{x}}$
- Normalised Bias: $NB = \frac{\sum y}{\sum x} - 1$ (NB < 0 means underestimation of MRR with respect to the 2DVD)
- Correlation coefficient: $cc = \frac{(x \cdot y) - (\bar{x} \cdot \bar{y})}{std(x) \cdot std(y)}$

The Stratiform/Convective (C/S) algorithm proposed by Bringi et al. (2009) has been applied to the 2DVD data ..

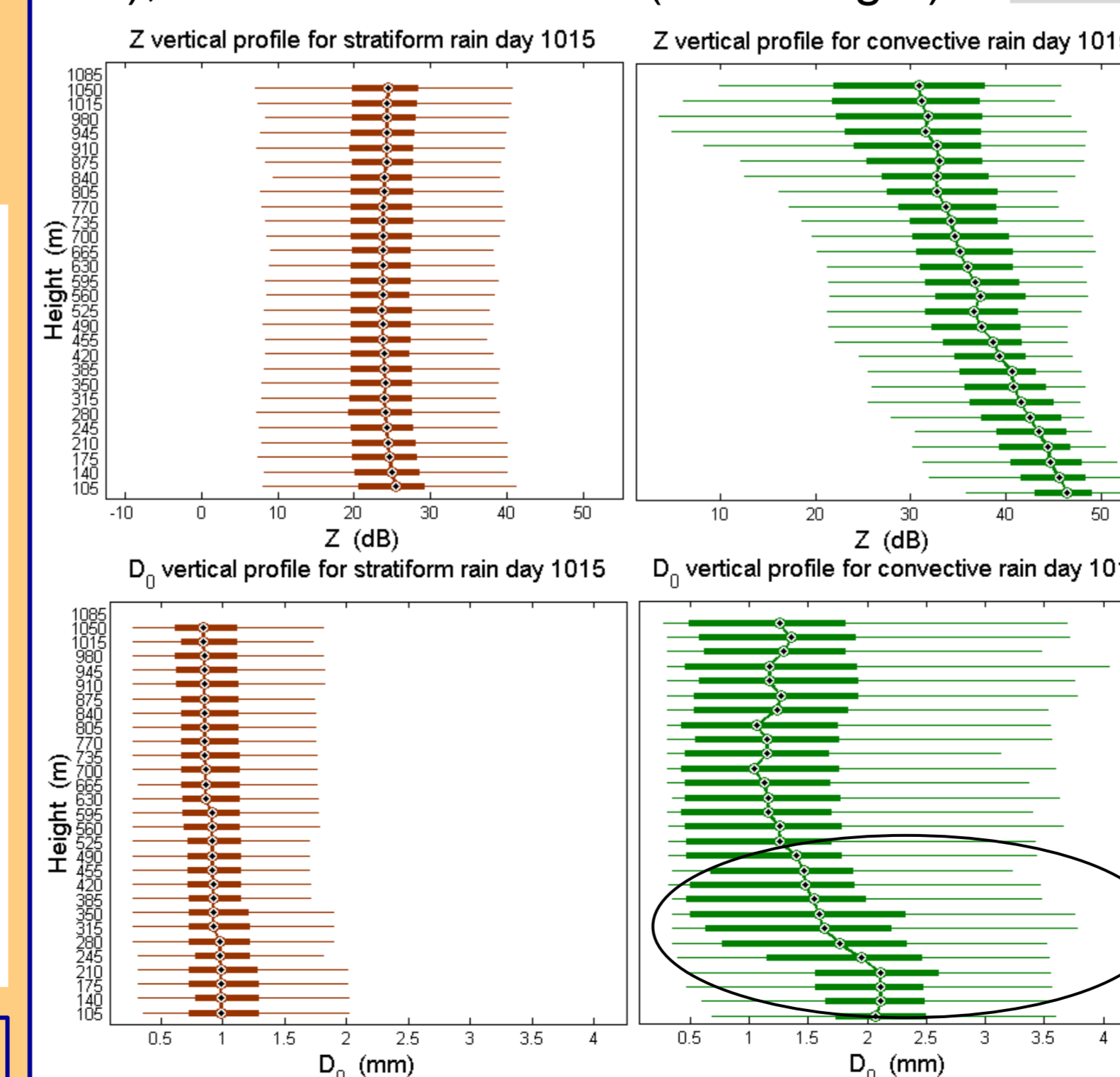
The reflectivities of all the events are shown in the following scatterplot.



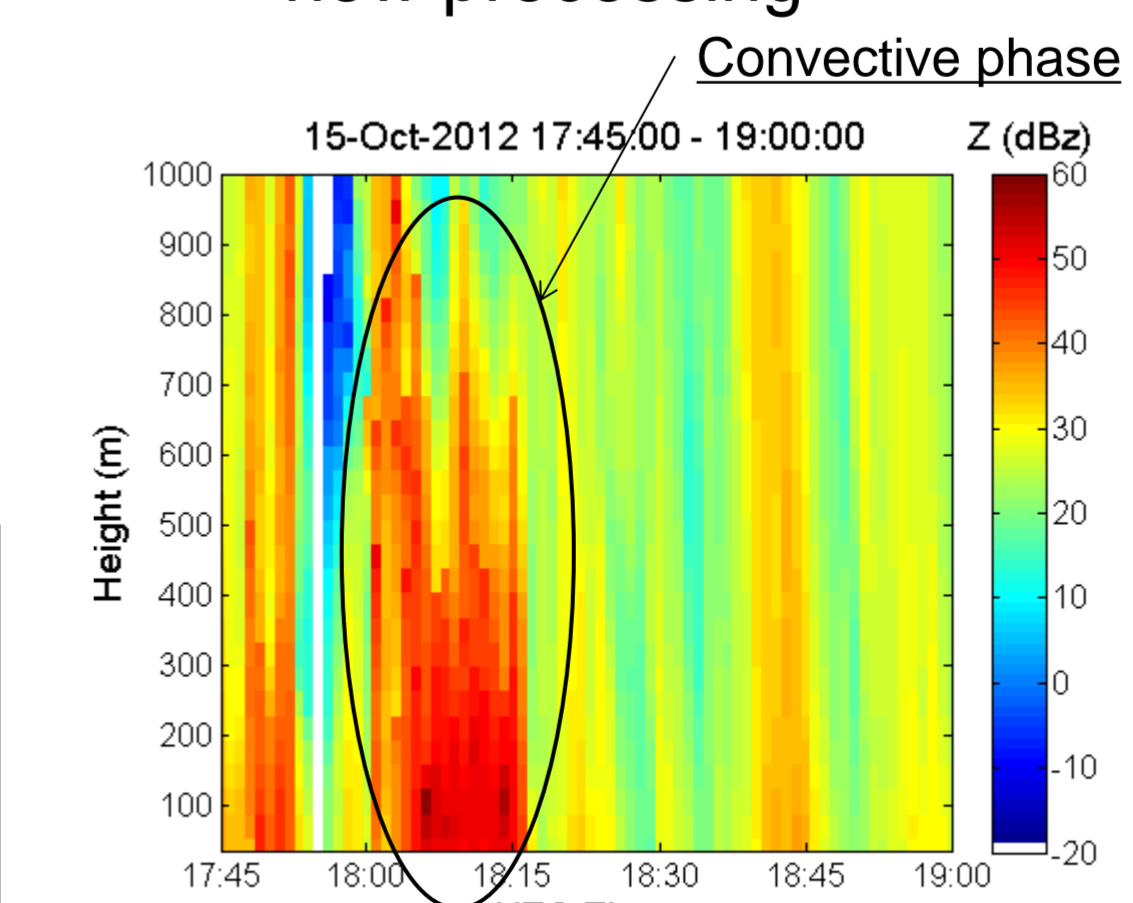
The proposed processing allows a **better agreement** between MRR and the 2DVD.

Case study: 15 October 2015

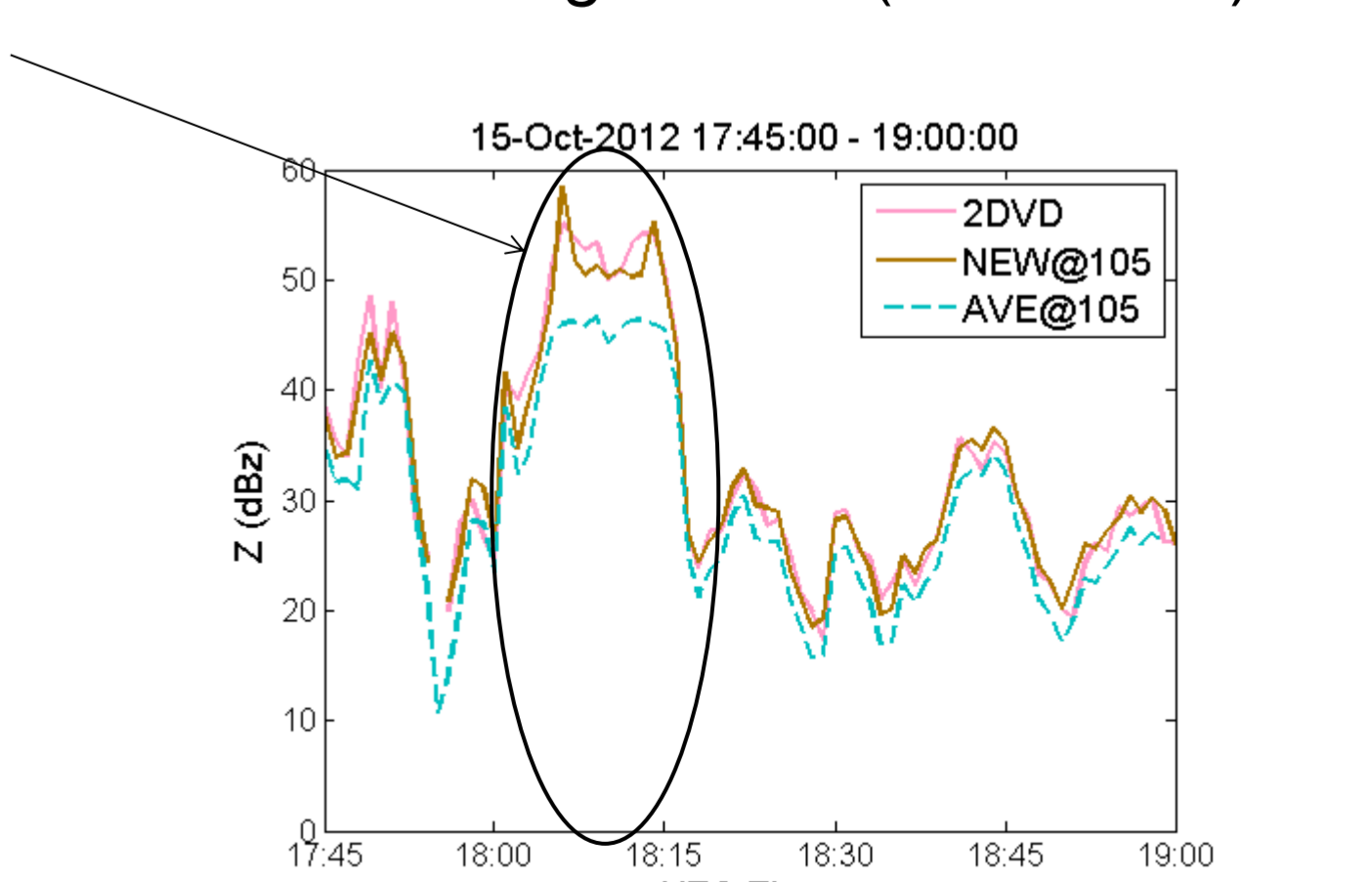
Box plot of Z and D_0 at the different heights during stratiform rain (on the left), and convective rain (on the right).



vertical profile of reflectivity obtained through the MRR new processing



Time series of reflectivity of 2DVD, from MRR new processing (NEW@105), and from *Averaged data* (AVE@105)



The increase of D_0 from ~500m AGL to the ground means drops become larger (drop sorting or predominance of coalescence).

References: Adirosi, E., Baldini, L., Roberto, N., Gatlin, P., Tokay, A., *Atmos. Res.*, in press (2015); Giangrande, S. E., Collis S., Straka J., Protat A., Williams C., Krueger S., *J. Appl. Meteor. Climatol.*, 52, 2278–2295 (2013); Maahn, M., Kollias, P., *Atmos. Meas. Tech.*, 5, 2661–2673 (2012); METEK, 2012., MRR Physical Basics, (Update of 13 March 2012) Elmshorn, 20 pp., Metek mbH; Peters, G., Fischer, B., Münster, H., Clemens, M., *J. Atmos. Ocean. Technol.*, 44, 829–842 (2010).